Office of Energy Efficiency and Renewable Energy

Office of the Biomass Program

Multiyear Plan
2003 to 2008

Preface

This multiyear planning document provides the strategic five-year plan for the Office of the Biomass Program (OBP), one of eleven offices under the purview of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (DOE/EERE). The OBP was recently formed to integrate and consolidate EERE activities in biomass energy research and development, and brings together technical components from several different offices within EERE. This document is the first strategic planning effort undertaken by the newly integrated office.

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1.0 Introduction

1.1 Office of Energy Efficiency and Renewable Energy

The mission of the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality and economic health. EERE accomplishes this mission through public-private partnerships that: enhance energy efficiency and productivity, promote the development of clean, reliable, affordable energy technologies, and expand the energy choices available to Americans.

In order to focus its efforts on the Nation's energy problems and achieve the greatest possible benefits from its programs, EERE has established nine portfolio priorities. These priorities serve to guide the portfolio decision-making process and support EERE goals for a secure energy future.

The use of renewable energy resources is a key tenet of the EERE mission and a recurring theme in its priorities. Today, the U.S. economy is dominated by technologies that rely on fossil energy (petroleum, coal and natural gas) to produce fuels, power, and a wide range of chemicals. There are, however, many compelling reasons to expand our energy choices to include more renewable sources such as biomass, solar, wind, and geothermal energy. Our growing dependence on foreign oil, for example, exposes the economy to critical disruptions in supply and could potentially impact national security. Volatility in the price and availability of fossil energy create economic and social uncertainties for businesses and individuals alike.

EERE Portfolio Priorities

- *Dramatically reduce or even end dependence on foreign oil*
- *Reduce burden of energy prices on the disadvantaged*
- *Increase the viability and deployment of renewable energy technologies*
- *Increase the reliability and efficiency of electricity generation, delivery and use*
- *Increase the efficiency of buildings and appliances*
- *Increase the efficiency/reduce the energy intensity of industry*
- *Create the new domestic bioindustry*
- *Lead by example through Government's own actions*
- *Change the way EERE does business*

Biomass is an abundant natural and renewable domestic resource that has the potential to supplement our fossil energy supply and help create a more secure energy future. Within the continental U.S., we can grow and harvest several hundred million tons of additional plant matter per year on a sustainable basis. Many of the chemicals and fuels that are now created from petroleum could be produced from domestic biomass, and with fewer environmental impacts. A bioindustry will provide avenues for productive uses of agricultural and forestry wastes, reducing the need for landfills and decreasing forest fire hazards.

1.2 Office of the Biomass Program

1.2.1 Background

Biomass has significant potential as an energy resource, provides an opportunity to enhance U.S. energy security, and supports the national mission and priorities of DOE. To take advantage of this valuable resource EERE established the Office of the Biomass Program (OBP) to foster development of the technologies needed to drive the growth of a new bioindustry.

The OBP emerged in 2002 as part of EERE's effort to streamline its organization and to improve the delivery its technologies. The reorganization was a response to the President's Management Agenda for Fiscal Year 2002, and the DOE/EERE Strategic Program Review (completed earlier in 2002).

The OBP brings together three programs that previously conducted biomass R&D under separate EERE offices – biofuels, biopower, and the Agriculture Industries of the Future initiative. OBP also incorporates activities that were previously conducted under the National Biobased Products and Bioenergy Coordination Office (see Section 1.3, Legislative Authority).

The new structure establishes an integrated program for biomass technology R&D, and will enable more effective use of EERE resources in this area.

Biomass *is produced from water and carbon dioxide by the process of photosynthesis. Primary biomass is produced by agriculture and forestry and includes energy crops such as short rotation trees, grasses and aquatic plants. The harvesting of these resources generates secondary forms of biomass such as straw, stover and forest residues in addition to lumber, pulpwood, and grains. Additional secondary resources includes processing residues and byproduct streams from food, feed, fiber and materials production. A growing quantity of biomass is tertiary in nature and includes post consumer residue streams from urban activities such as, fats, greases, oils, construction and demolition wood, as well as animal residues from concentrated animal feed operations.*

1.2.2. Mission of OBP

The mission of OBP is to partner with U.S. industry to foster research and development on advanced technologies that will transform our abundant biomass resources into clean, affordable, and domestically-produced biofuels, biopower, and high-value bioproducts. The results will be economic development, energy supply options, and energy security.

OBP activities directly support the overall mission and priorities of DOE/EERE. OBP technology development and implementation activities will directly contribute to the creation of a new bioindustry, and will reduce U.S. dependence on foreign oil by supplementing the use of petroleum for fuels and chemicals.

1.2.3 Program Structure

OBP pursues its mission through competitively awarded, cost-shared RD&D partnerships with industry, academia, national laboratories, and private research institutes. OBP makes investments based on detailed market and technology analysis, and collaboration with leaders and technology experts in the industry.

OBP structures its activities within two areas - Advanced Biomass R&D and Systems Integration (see Figure 1-1). This structure reflects the technology development pathway pursued by OBP. Advanced Biomass R&D addresses the early stages of technology development. Systems Integration reflects the later stages of technology development and the implementation process, including validation, and demonstration of technology. The strategies and technical elements of these programmatic areas are outlined in Chapter 3.

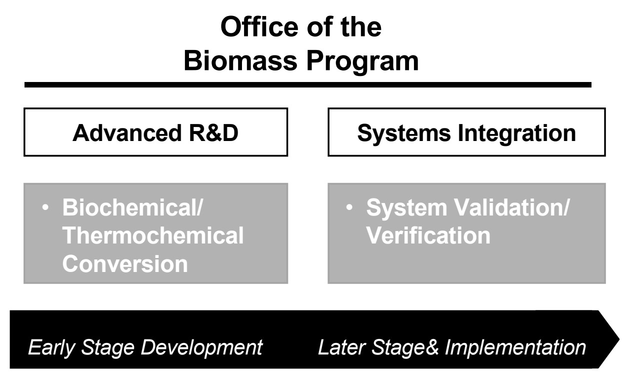

Figure 1-1 Program Structure for OBP

1.3 Legislative Authority

1.3.1. Primary Legislative Directives

The legislative authority behind the Office of the Biomass Program is rooted in legislation dating to the late 1970's. Over the last decade interest in biomass as an energy resource has spurred the passage of several laws that encourage the expansion of the bioindustry (see Figure 1-2).
These legislative actions support the technology development programs needed to advance the industry. They provide direction for OBP's research

programs and R&D portfolio. Appropriations made under Title XII of the **Energy Policy Act of 1992**,for example, supported some of the early research in biobased fuels and power systems that form the foundation for current OBP R&D programs.

In 1999, Executive Order 13134 set policies to stimulate development of biobased technologies, and established the National Biobased Products and Bioenergy Coordination Office, under which some early OBP activities were conducted. Today the functions of the National Coordination Office are performed jointly under the purview of the OBP and USDA.

The **Biomass R&D Act of 2000** superseded Executive Order 13134, creating a legislative mandate for OBP. In addition to funds appropriated for biomass R&D under the general authority of the Secretary of Energy, the Act provides funds for OBP research under Section 307, *Biomass Research and Development Initiative*. OBP responds directly to the Act by conducting R&D to address some of the key technical issues outlined in the legislation.

Role of the Federal Government

"Congress finds that....because of the relatively short-term time horizon characteristics of private sector investments, and because many benefits of biomass processing are in the national interest, it is appropriate for the Federal government to provide pre-commercial investment in fundamental research and research-driven innovation in the biomass processing area ...."

Biomass R&D Act of 2000

1.3.2 Other Legislative and Administrative Drivers

The efforts of the current administration to develop an energy plan will have important implications for the bioindustry and the OBP. The National Energy Policy (NEP) report, commissioned by President G.W. Bush, reviews the Nation's energy situation and presents a strategy to achieve a reliable energy structure that will support our quality of life and still maintain protection of the environment.

The increased use of renewable energy, including biomass, is an integral part of the NEP strategy and provides further justification for OBP activities in this area. The Executive Branch is now working with Congress to enact a National Energy Policy which will provide future guidance for this program. Under the new energy policy, the OBP's R&D activities will continue to support our national goals for energy security.

Figure 1-2. Legislative Mandates Behind the Office of the Biomass Program

Biomass R&D Act of 2000 (Agricultural Risk Protection Act of 2000, Title III) – *directs the U.S. Departments of Energy and Agriculture to integrate technology R&D programs to foster a domestic bioindustry producing fuels, power and chemicals. For purposes of research coordination and oversight, the Act establishes the Biomass R&D Board and the Biomass R&D Technical Advisory Committee. Section 307, Biomass R&D Initiative, authorizes grants, contracts and financial assistance for biobased products R&D in specific technical areas. The Act replaces Executive Order 13134, Developing and Promoting Biobased Products and Bioenergy, issued in 1999.*

Farm Bill 2002, Title IX – *is the first farm bill ever to include an energy title. The Bill contains five programs providing mandatory funding for bioenergy activities, and reauthorizes the Biomass R&D Act of 2000 through 2007. The Bill mandates the purchase of 'environmentally preferable bioproducts' by Federal agencies, and provides grants for development of biorefineries (Section 9003). The Bill establishes incentives and grants for biodiesel, fuel grade ethanol, and use of renewable energy in rural enterprises.*

Energy Policy Act of 1992, Titles III, IV, V and XII (EPAct) - *reauthorized portions of the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989, expanded renewables R&D programs, and established new incentives for the use of biomass (and other alternatives) for power and fuels. Title XII provides appropriations for demonstration and commercial application projects in biobased fuels and power systems, including conversion of cellulosic biomass to fuels, ethanol production, and direct combustion or gasification of biomass. Title XII also creates an 'Alcohol From Biomass' R&D program to promote advanced alcohol production technologies (ethanol and methanol). Titles III, IV and V encourage the use of alternative fuels in the transportation sector through fleet incentives.*

2.0 Benefits, Opportunities and Strategic Goals

2.1 National Benefits and Opportunities

Using our indigenous biomass resources to supplement the U.S. energy supply will yield a multitude of benefits for the Nation. Biomass can be used to fuel our cars, heat homes, and provide many of the diverse products that are essential to daily life. Using biomass as an energy resource will allow the U.S. to reduce its dependence on foreign oil, stimulate economic growth, and positively impact the environment.

2.1.1 Energy Potential of Biomass Resources

Biomass resources in the United States are abundant and renewable, and offer tremendous potential to supplement our current energy resources. Current total available domestic biomass, beyond its current use for food, feed, and forest products, is between 500-600 million dry tons per year for the period 2010-2020[1]. These biomass resources represent about 3-5 quads of delivered energy or as much as 5-6 percent of total U.S. energy consumption.

In terms of fuels and power, that translates into 60 billion gallons of fuel ethanol or 160 gigawatts of electricity. This is enough energy to meet 30 percent of U.S. demand for gasoline or service 160,000 households with power[2]. If only 10 percent of the biomass resource were converted to chemicals, the result would be 25-30 million tons of products or about five times the current production of industrial bioproducts[3].

Based on these estimates, available domestic biomass represents a potentially significant energy resource. The efforts of OBP will greatly increase the available biomass potential through advances in technology and changes in public policy and infrastructure.

2.1.2 U.S. Energy Security

Overall, U.S. consumption of energy far outpaces domestic production for all sources of energy. Decreasing U.S. dependence on imported oil is an issue of national security. This dependence increases our vulnerability to supply disruptions and amplifies the impacts of price volatilities. Biomass-based fuels, products and power will significantly reduce this dependence.

Oil imported into the U.S. has been rising over the last three decades, and now accounts for approximately 53% of the U.S. oil supply (see Figure 2-1). Approximately 6.4 billion barrels per year (~70%) are used to produce transportation fuels, while nearly half a billion barrels of oil per year (~5%) are used to manufacture high-value plastics, pharmaceuticals, paints, detergents, and other consumer products. The remainder is used to heat commercial and residential buildings and produce power.

Displacing fossil energy with biomass-based fuels, power and products will allow the U.S. to meet demand for fuels, products and power while reducing dependence on imported oil and increasing energy security. The efforts of OBP will develop and help to commercialize technologies that produce fuels, products and power from biomass. These will directly supplant imported oil usage and develop a more secure domestic source of energy.

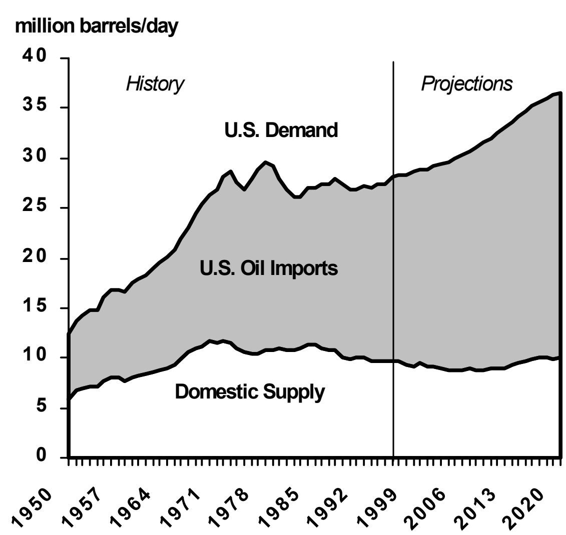

Figure 2-1 U.S. Oil Production and Consumption [DOE/EIA Annual Energy Review 2000, Annual Energy Outlook 2001]

2.1.3 National and Rural Economic Growth

The creation of a new bioindustry, which is a strategic goal for EERE and a primary driver for OBP, will provide new opportunities for economic growth. History has shown that creating new industries yields the highest return in terms of jobs and domestic value. Developing our domestic sources of energy will also enhance our competitiveness in foreign markets.

A domestic bioindustry will require an increase in production and processing of biomass. This will directly impact rural economies by creating new cash crops for farmers and foresters, many of whom currently face economic hardship. New processing, distribution, and service industries will be established in rural communities, positively impacting rural economic growth. As the agricultural and forestry industries begin to provide feedstock for more than just food, feed and fiber, they will become an integral part of the transportation and industrial supply chain.

2.1.4 Environmental Benefits

Biomass technologies will positively impact the environment by offsetting the use of fossil fuels and associated pollutant emissions. There is also the potential to reduce the generation of harmful wastes associated with the manufacture of chemicals from petroleum. Other environmental benefits include stemming the growth in emissions of carbon dioxide, better management of particulate emissions, reducing soil erosion, and reducing forest fire risks by making productive use of thinnings from forest lands.

2.2 Challenges in Creating the Bioindustry

Advances in science and technology will be key to the development of new bioprocessing systems and biorefineries. Integrated, multi-disciplinary research activities will be necessary to address major technical challenges, make progress toward demonstration and commercialization of new technology, and create a domestic bioindustry. OBP's well-coordinated research effort will create and nurture partnerships among stakeholders in industry, government and academia. Section 4 discusses the role OBP will have in building partnerships and coordinating R&D. There are a number of technical barriers associated with feedstock variability and biomass conversion processes. These are the focus of the Technical Plan (Section 3.0).

2.2.1 Advanced R&D

The overarching R&D challenge for OBP is to maximize the efficiency and minimize the costs of transforming plants to useful products, while keeping sustainability in mind.

Variability and supply logistics of biomass - Biomass resources vary in the type and amount of biomass available. They vary widely in physical and chemical composition, size, shape, moisture content, bulk densities, and seasonal availability. Handling, storage and transportation are also challenging issues with biomass resources.

Conversion to fuels, chemicals and power - Plant cell walls are designed to withstand drought, pests and disease, and to keep plants standing upright. These same qualities make biomass resistant to conversion to fuels, power and chemicals by thermal or biochemical processes. To cost-effectively convert biomass with a biochemical process, advances will be needed in pretreatment as well the conversion technology. Thermochemical processing creates a synthesis gas (syngas) that can contain unwanted mineral components and particulates. These contaminants will need to be removed for syngas to be a cost-effective and environmentally viable option for products and power.

Sustainability - This is a key criterion for establishing a robust bioindustry. Consideration of environmental soundness, stewardship of resources are essential. OBP recognizes that careful analyses and consideration of sustainability issues must be undertaken simultaneously with R&D, and structures its programs accordingly.

2.2.2 Systems Integration

A successful bioindustry will require facilities with well-integrated bioprocessing systems that are able to produce fuels, chemicals and power from a variety of feedstocks. Effective integration of feedstock delivery systems to final product processing and purification will be major challenges. The technical and financial risk involved with new technology, as well as lack of proven technology performance, will largely influence the growth of the bioindustry.

Technical and financial risk - Considerable risk will be involved in building new biomass processing facilities, primarily due to the capital cost and performance uncertainties of new, unproven technology. These uncertainties are compounded by externalities such as regulatory requirements and government policies.

Factors associated with performance and cost in new bioprocessing facilities include: facility complexity, capital investment for new technology, heat and material balance data, waste handling, and feedstock handling. To reduce risk, OBP sponsors R&D to solve many of the uncertainties these areas.

Performance validation - Validation of integrated processing systems will confirm reliability, lower operating costs through optimization, and minimize the cost of environmental compliance. Understanding the risk associated with bioprocesses will allow investors to better judge capital investment needs, process performance, and feedstock and product prices. OBP works with industry to verify performance and operating characteristics of these integrated systems.

What is a Biorefinery?
A biorefinery processes biomass into value added product streams. These can range from biomaterials to fuels such as ethanol and fuel gases, or key intermediates for the production of chemicals and other materials. Biorefineries are based on a number of processing platforms using mechanical, thermal, chemical and biochemical processes.

2.3 Goals and Objectives

2.3.1 Strategic Goals

In keeping with DOE/EERE priorities, OBP has established a long-term strategic goal for reducing U.S. dependence on foreign oil. This will be accomplished by supplanting the use of petroleum with biomass for the production of fuels, chemicals and heat/power.

Figure 2-3. Biomass R&D Technical Advisory Committee Goals for 2020

- *10 percent of transportation fuels will be biomass-derived by 2020.*
- *Biopower will meet 5 percent of total industrial and utility power demand in 2020.*
- *Biomass-derived chemicals and materials will account for 18 percent of the U.S. production of targeted chemicals in 2020.*

OBP has also embraced the long-range goals set by the Biomass R&D Technical Advisory Committee in their recent vision document[3], as shown in Figure 2-3. The technical strategy and program goals of OBP have been designed to help meet these targets.

2.3.2 Multiyear Plan Outcomes

This five-year Multiyear Plan will result in the following 6 outcomes:

- *A complete analysis of biorefinery options by 2004 that identifies the most promising processes, products. This will then form the primary emphasis of the program.*
- *Verify technology components such as pretreatment and enzymatic hydrolysis at existing grain processing biorefineries by 2004.*
- *Demonstrate an integrated process for fuels production from biomass at an appropriate scale by 2005.*
- *Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals and power by 2007.*
- *Demonstrate a fully integrated black liquor gasification system for heat and power production at a commercial pulp mill by 2009.*
- *Help U.S. industry to establish the first large-scale sugar biorefinery based on agricultural residues by 2010.*

3.0 Technical Plan

3.1 Technical Approach

This Multiyear Plan is designed addresses the gaps, barriers, and opportunities that limit the development of a new bioindustry. The OBP approach is to focus on two important technology platforms- sugars and syngas (see Figure 3.1). These are the high volume chemical intermediates that hold the most promise for achieving significant advances over the next 5-7 years. By concentrating resources on these platforms OBP can expand upon developments by existing industries and focus efforts on new biomass opportunities.

OBP fosters R&D in both platforms to improve existing processes and to develop new technologies. This R&D seeks to maximize the production of sugar and syngas and their conversion into fuels and products, and to effectively integrate the new technology into plant operations. This includes reducing technical and financial risk through technology validation. To ensure that a viable feedstock infrastructure is in place to support new plants, OBP conducts activities to address feedstock supply issues. An overview of efforts planned for technology platforms, utilization and feedstock is provided in the following sections.

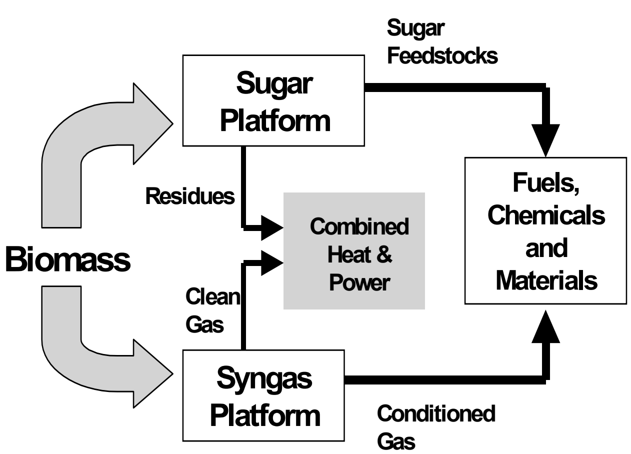

Figure 3-1 Sugar and Syngas Platforms for the Production of Fuels, Chemicals and Power

3.2 The Biomass to Sugars Platform

3.2.1 Background on the Sugars Platform

The sugars platform involves the breakdown of biomass into component sugars by a range of chemical and biological processes. As shown in Figure 3-2, biomass is first subjected to pretreatment to hydrolyze the hemicellulose and expose the cellulose to attack by enzymes, a process that produces an intermediate (C5) sugar stream. The cellulose then undergoes enzymatic hydrolysis to produce glucose, which can be converted to fuels or chemicals. Residues are separated and used for power or other products.

Today's industrial sugar platforms exist in the corn processing industry (wet and dry mill

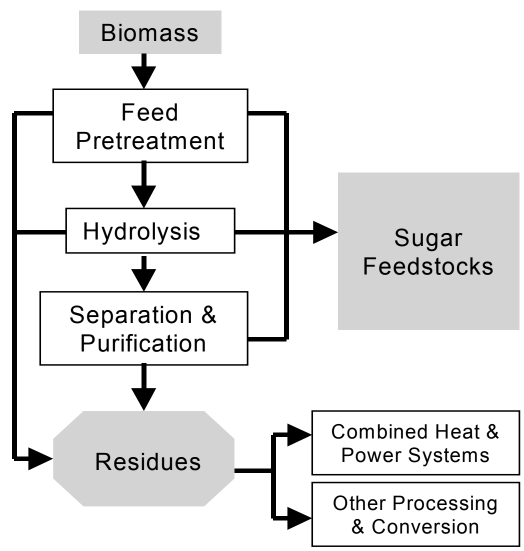

Figure 3-2 Platform for Conversion of Biomass into Sugars

operations). In these operations, the starch in corn grain is the feedstock that is hydrolyzed to release glucose for production of fuel ethanol and other chemicals.

The existing two-billion gallon per year fuel ethanol industry can serve as the basis for the next generation of technology for creating products from sugars. This expansion will require a shift toward new, inexpensive, non-traditional biomass feedstock to open up new markets for sugar-derived products and facilitate the growth of the bioindustry.

Corn stover, for example, represents a large, accessible, low cost source of sugars. The delivered cost of sugars from corn grain currently used to produce ethanol is around 5.5 cents per pound (corn price of $2/bushel). By contrast, the delivered cost of sugars available from corn stover is only about 3 cents per pound[4] (a price of $35 per ton).

New technologies will be needed to cost-effectively convert stover and other biomass feedstock to sugars. As outlined in the remainder of this technical plan, OBP's role in technology development and deployment for this platform will be to conduct research and development in feedstock pretreatment and enzymatic hydrolysis of sugars, with an initial emphasis on corn stover.

3.2.2 Status of Biomass to Sugar Technology

Corn grain processing - The existing grain processing industry is based primarily on the conversion of starch in corn grain to sugar, ethanol and other products. In its early days, this industry hydrolyzed starch to produce glucose using acid hydrolysis. Today, acid technology has been replaced by enzymes (biocatalysts) that can hydrolyze glucose from starch much more efficiently and cost effectively. However, modern grain ethanol plants are approaching the limits of their potential yield of ethanol from corn starch. At the same time, these plants have achieved much greater energy efficiency.

Sugars from lignocellulosic biomass - The DOE has historically supported R&D to convert lignocellulosic biomass into sugars. As with corn grain to ethanol technology, biomass conversion has shifted from the use of acid technology to the use of enzymes (cellulases) to hydrolyze cellulose to glucose, coupled with some form of acid pretreatment to release hemicellulosic sugars. Significant improvements have been made in the cost and effectiveness of commercial cellulase enzymes.

3.2.3 Technical Barriers to Commercial Biomass to Sugar Biorefineries

The key technical barriers to the *biomass-to-sugar platform* range from insufficient knowledge of fundamental chemistries to technological deficiencies in reactor and equipment design (see Table 3-1).

Pretreatment of biomass - Pretreatment is required to open the structure of biomass and allow efficient enzyme hydrolysis of the cellulose, which is protected by a sheath of lignin and hemicellulose. Advances in pretreatment technology are needed to improve the enzymatic digestibility of biomass and facilitate downstream processing into sugars. This will require better understanding of pretreatment chemistries, as well as new, more reliable reactor and equipment design.

Enzymatic hydrolysis - Current enzyme hydrolysis is limited by the low activity of the biocatalyst and the resulting high costs of production. A newly developed generation of enzymes for hydrolyzing cellulose to glucose will provide significant cost-reductions in the cost of production for ethanol, and enable expansion of the industry into new commodity-scale products based on sugars.

Table 3-1. Technical Barriers to the Biomass to Sugar Biorefinery

Processing Area	Key Technical Barriers
Pretreatment	Need for advances in understanding: • The chemistry of biomass pretreatment and hydrolysis of hemicellulose. • The impact of biomass structure on pretreatment • The root causes of recalcitrance • The cost of pretreatment options • Reactor design fundamentals • Equipment reliability • Materials of construction
Enzymatic Hydrolysis	• Low reactivity of current commercial enzymes • High cost of cellulase enzymes • High cost of enzyme production • Enzyme biochemistry

3.2.4 Programmatic Objective for the Biomass to Sugar Platform

The Programmatic Objective for the sugar platform is:

To develop the capability for using new, inexpensive sources of biomass to produce sugar feedstock in the biorefinery.

This MYPP will result in the following Outcomes under this objective (from 2.3.2):

Verify technology components such as pretreatment and enzymatic hydrolysis at existing grain processing biorefineries by 2004.

Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals and power by 2007.

3.2.5 Technical Plan for the Biomass to Sugar Platform

Existing biorefineries will serve as the initial testing grounds for new technologies in pretreatment and enzymatic hydrolysis.

Pretreatment - Pretreatment R&D will address the chemical and physical barriers to hydrolysis in pretreatment, including enzymatic hydrolysis. Advanced pretreatment R&D will focus on pretreatment fundamentals and process considerations and capabilities.

Organizations involved in pretreatment research, include NREL, the University of Louisville, and the Biomass Refining Consortium on Applied Fundamentals and Innovation (CAFI) - comprised of several universities including Dartmouth, Auburn, Michigan State University, University of Sherbrooke, and University of British Columbia. Non-U.S. partners include the Mid-Sweden University, Umeå University (Sweden), and Natural Resources Canada.

OBP's pretreatment research will result in improved reactor designs, more accurate quantification of capital costs, and engineering improvements. Emerging technologies will include potential new pretreatment options, options for best use of byproducts such as lignin, and improved analytical capabilities.

Enzymatic hydrolysis - The focus of activities in this area will be on the development and deployment of new enzyme technology for conversion of corn fiber to ethanol in existing corn dry mills. Corn fiber is a captive cellulose source in existing ethanol plants. These plants will serve as the test beds for new hydrolysis technology.

Initial R&D will focus on new enzymes tailored to provide high yields of sugars from a corn stover feedstock. These enzymes will enable the development of the first lignocellulosic biorefineries. Major partners in enzyme research include NREL, enzyme technology companies, the University of Arkansas, Cornell University, and the Colorado School of Mines.

This research is expected to lower costs for producing enzymes and increase the potential limits of improvement possible in enzyme performance. Research will also improve fundamental understanding of the enzymatic process through characterization of the cellulase function and cellulase-cellulose interaction.

3.2.6 Key Milestones for the Biomass to Sugar Platform

Key milestones for the sugars platform are shown in Table 3-3.

Table 3-3. Milestones for the Biomass to Sugar Platform

Processing Area	FY 03-04	FY 04-05	FY 06-10
Pretreatment	• Assess the current status and estimate the ultimate potential of pretreatment technologies under development using consistent methodologies.	• Develop global kinetics for classes of pretreatment technologies to predict performance.	
Enzymatic Hydrolysis	• Enzyme subcontract achieves ten-fold cost improvement targets (Genencor ‘03)	• Enzyme subcontract achieves ten-fold cost improvement target (Novozymes ‘04)	• Start-up of sugar platform demonstration

3.3 The Synthesis Gas (Syngas) Platform

3.3.1 Background on the Syngas Platform

The biomass syngas platform involves gasifying biomass to simple chemical building blocks which can be transformed to fuels, products, power and hydrogen. Components of this platform include feed preparation, the biomass gasifier, and a gas treatment and cleaning train (see Figure 3-3). The initial syngas contains particulates and other contaminants and must be cleaned and conditioned prior to use in fuels, chemical or power conversion systems (e.g. catalyst beds, or fuel cells).

An advantage of the gasification process is that it can, in principle, convert nearly all the biomass feedstock into syngas, even those components that are difficult to process by chemical or biological means, such as residues. Gasification provides a means to optimize biorefinery operations by utilizing residues or waste streams that might otherwise be land-filled or used for low-value products.

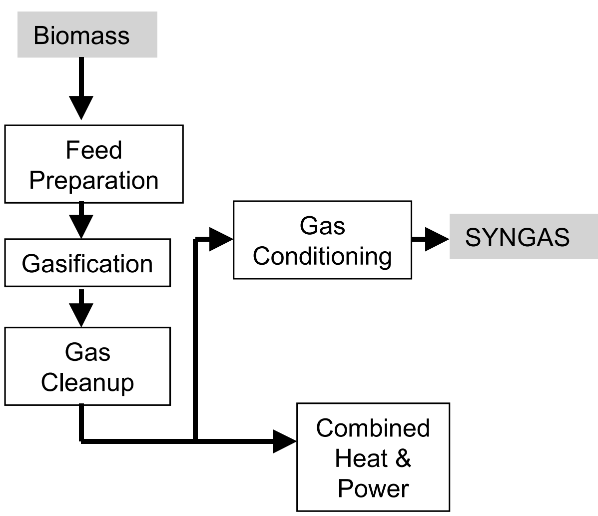

Figure 3-3 Biomass Syngas Platform

The cleaned syngas stream can be converted into liquid fuels, hydrogen or chemicals using conversion technology that has been developed by the petroleum and chemical industries. Syngas can also provide fuel for Combined Heat and Power production (CHP).

OBP will explore the potential use of gasification as a means of producing syngas and optimizing biorefinery outputs. As outlined in the following sections, gas clean-up and treatment and reactor materials and design are two areas where technology advances will be needed.

3.3.2 Status of Syngas Platform Technology

Biomass gasification technologies have been a subject of commercial interest for several decades. Interest in biomass gasification increased substantially in the 1970s because of uncertainties in petroleum supplies, with most of the development occurring in small scale systems. Low-energy gasifiers are now commercially available, and dozens of small-scale facilities are in operation.

In the 1980s, government and private industry sponsored R&D for gasifier systems primarily to gain a better understanding of reaction chemistry and scale-up issues. In the 1990s combined heat and power was identified as a potential near-term opportunity for biomass gasification because of incentives and favorable power market drivers. R&D concentrated on integrated gasification combined cycle (IGCC) and gasification co-firing demonstrations, which culminated in a number of commercial-scale systems. In the U.S., projects mostly processed very recalcitrant feeds such as bagasse and alfalfa.

Black liquor gasification has many potential advantages in pulp mills, either as a replacement or supplement for the current Tomlinson recovery boiler. The pulp and paper industry's interest in gasification as an alternative to Tomlinson recovery boilers has peaked recently as the industry faces the need to replace most these aging boilers over the next 10-15 years.

However, there are serious technical challenges still left to be resolved before gasification technology can be successfully integrated into an operating commercial pulp mill. Currently, there are only a few U.S. technology developers that are actively pursuing commercialization of black liquor gasification technology. These developers have conducted pilot-scale tests and have laid the groundwork for commercial demonstration efforts.

Currently, OBP is co-funding a series of commercial demonstrations and technology support projects designed to accelerate the commercial viability of gasification as a replacement to Tomlinson recovery boilers.

3.3.3 Technical Barriers for the Syngas Platform

The key technical barriers to developing a robust *biomass-to-syngas* platform range from feed pretreatment and properties, gas clean-up, containment, to process control (see Table 3-3).

Gas cleanup - The raw gases from biomass systems do not meet strict quality standards for downstream catalysts as well as some power technologies (fuel cells or fuel cell/turbine hybrids), and will require gas cleaning and conditioning to remove contaminants (tar, particulates, alkali, ammonia, chlorine and/or sulfur).

Containment (materials of construction) - Experience with black liquor gasifiers has shown that the reactions are difficult to contain, and long-term and economically acceptable approaches are yet to developed. Solutions involve metals for reactor shells and internals, refractories to line containment vessels, vessel design, and increased knowledge of bed behavior and agglomeration.

Process control and optimization - Effective process control will be needed to maintain gasifier performance and emissions at target levels with varying load, fuel properties, and atmospheric conditions. Validated computational fluid dynamic models and rugged sensor systems are two important challenges in this area.

Black liquor gasification - Commercialization of black liquor gasification technology has been hindered by issues of feed pretreatment, gas cleanup, containment, process control, and integration of operations within the mill (steam, power, pulping, recovery of pulping chemicals).

Table 3-3. Technical Barriers to Production of Syngas From Biomass

Processing Area	Key Technical Barriers
Gas Clean-Up	• Low syngas quality due to chemical contaminants, tar formation and particulates. • Unproven gas cleanup and conditioning technologies and systems.
Containment	• Reliability and cost of materials for biomass gasifier vessels and refractories.
Smaller-scale Gasifier Systems	• Need for smaller syngas to synfuels catalytic conversion processes for distributed refineries
Process Control and Optimization	• Inadequate control systems technology for gasifier systems and subsystems.
Biomass and Black Liquor Gasifiers	• Feed pretreatment, gas cleanup, reliability/safety of containment vessels. • Integration of mill operations • Optimization of hot gas cleaning and turbine design for black liquor gasifiers

3.3.4 Programmatic Objective for the Syngas Platform

The Programmatic Objective for the syngas platform is:

To Produce a clean syngas from a range of biomass feedstock that is compatible with existing and advanced processes for the production of fuels, chemicals and power.

This MYPP will result in the following Outcomes under this objective (from 2.3.2):

Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals and power by 2007.

Demonstrate a fully integrated black liquor gasification system for heat and power production at a commercial pulp mill by 2009.

3.3.5 Technical Plan for the Syngas Platform

As its first priority, OBP will develop a series of integrated technical plans for RD&D to address key barriers in biomass gasification for syngas production. The planning process will incorporate existing gasification development plan elements and time lines (e.g. Forest Products Agenda 2020).

To facilitate the development of advanced biomass gasification systems, OBP will conduct advanced R&D to address technical barriers related to gas cleaning and treatment and control of the gasification process.

Gas cleaning and treatment - Significant advances in syngas cleaning and treatment are required to integrate with advanced syngas end-use technologies. OBP partners with the National Laboratories, universities, and industrial partners to develop and evaluate advanced concepts in particulate removal and catalytic conversion of problematic syngas components. Activities include:

- Analyzing hot gas particulate removal.
- Examining the use of catalytic tar reforming crackers.
- Analyzing large scale gas conditioning with catalysts.
- Evaluating the chemistry and kinetics of biomass gasifier tar formation and removal.

OBP is evaluating advanced concepts for particulate and tar removal in existing gasification test-bed facilities, and is exploring options for new thermal and catalytic removal and treatment technologies and materials. Research is expected to improve gas treatment system performance. Efforts will include gasification of conventional biomass, biomass residues, and black liquor.

A key activity is analyzing syngas treatment needs based on requirements for different end-uses. Through this analysis future research will be tailored to achieve syngas quality that meets specifications for multiple uses.

Process control and optimization allows improvement based on incremental changes in design, operation, or control. Examples of projects in this area include: development and design for control systems; dryer/evaporator/heater design and control; methods for introducing black liquor in controllable and optimal form; sensor development and integration into active process control; and coordination of sub-models into compatible and useful tools, possibly including use of sub-models as part of the control system.

Small-scale gasifier systems - OBP will conduct activities to build on existing and emerging smaller-scale syngas-to-synfuels catalytic conversion processes. The objective is to develop a distributable biomass gasifier that produces medium-BTU product gases. A solicitation will be issued for the adaptation of existing gasifiers to this need and to elicit promising new design concepts (Golden Field Office). DOE laboratories will provide technical support and catalyst development.

Biomass and black liquor gasifiers - OBP will conduct research and development necessary for the integration of biomass gasifiers into operating, commercial-scale biorefineries. The focus will be on addressing key technology barriers and fundamental information needs (e.g., formation and destruction of tars, upstream and downstream process impacts, containment materials, and process optimization).

Partners in this research will include national laboratories (National Energy Technology Laboratory, ORNL, Argonne National Lab, Sandia National Laboratory, and NREL), industry, universities, and the Gas Technology Institute. The OBP will build on technology knowledge gained from the intensive EERE Biopower Program and EERE Forest Products Industry gasification efforts of the1990s.

The outcome will be technologies, models, and knowledge that increase the likelihood of commercial success of gasifiers in operating biorefineries, beginning with the projects underway at two operating pulp mills.

3.3.6 Key Milestones for the Syngas Platform

Key milestones for the program are shown in Table 3-4.

Table 3-4. Milestones for the Syngas Platform

Processing Area	FY 03-04	FY 04-05	FY 06-10
Gas Cleanup	•Determine gas treatment needs based on target fuels, chemicals and CHP systems. •Resolve tar issues through integrated testing of candidate materials, catalysts, and technologies at appropriate scales. •Complete conceptual design, site zoning and permitting for high pressure gasification and gas cleanup test facility.	• Validate high pressure gasification facility and initiate high pressure gas treatment process development.	• Validate integration of gas treatment system with syngas based biorefinergy.
Smaller-scale Gasifier Systems	•Begin development of gasification systems appropriate for distributed biorefineries.	• Verify hydrogen production system and fuel cell operation.	• Validate integration of hydrogen production system or fuel cell operation with syngas-based biorefinery.
Biomass and Black Liquor Gasifier Development	•Establish commercial feasibility of direct and indirect causticizing to reduce gasifier's load on pulp mill lime kiln •Determine the feasibility of advanced pulping technologies in combination with gasification •Develop cost-effective gasifier containment vessel metals and refractories •Develop and validate detailed gasifier CFD models (low temperature gasifiers)	• Develop small-scale PDUs for scenario testing and process optimization • Establish the performance of innovative sulfur removal methods	

3.4 Utilization of Platform Outputs

3.4.1 Background on Utilization Technologies

The sugar and syngas platforms will provide the basic inputs for downstream conversion into fuels, high-value chemical products, and heat and power. In addition to primary products such as sugars and syngas, these platforms will also produce residues and byproducts streams that can be used productively. As shown in Figure 3-4, utilization of all platform outputs is needed to provide a range of products, supply energy to the biorefinery, and optimize profitability. Cost-effective utilization technologies that enable productive use of all biomass streams will be critical to the technical and financial success of future biorefineries.

Conversion to fuels and products - Technological advances are needed to enable cost-effective biological and chemical conversion of sugar feedstock and syngas to liquid fuels, chemicals and materials. Fermentation and catalytic conversion processes offer the most potential. For industry to invest in a new bioindustry, these utilization technologies must be economically viable and yield a flexible product slate that competes in the current marketplace.

Systems integration - Systems integration is a crucial component of utilization, as it impacts both performance and profitability and ultimately implementation of technology. Feedstock handling, sugar and syngas platform technology, conversion processes, energy production and process control systems all need to be well-integrated within the biorefinery. Validation, verification and demonstration of integrated bioprocessing systems will promote commercial acceptance and reduce technical and financial risk for new biorefineries.

Heat and power generation - Utilization technologies are needed to produce heat and power from the various biomass resources that will be available as biorefinery outputs (e.g., residues, syngas, byproducts, waste materials). Innovative technologies such as the gasification combined cycle and black liquor gasification represent potential cost-effective approaches for heat and power production in the biorefinery.

Analysis - OBP's efforts here provide an understanding of the effects of technology choices, and costs. It guides research planning toward critical areas, and reduces the risk associated with technology development. Analytical tools are also needed to support the development and deployment of new technologies for effective control and monitoring of feedstock supply, biomass processing, and product quality.

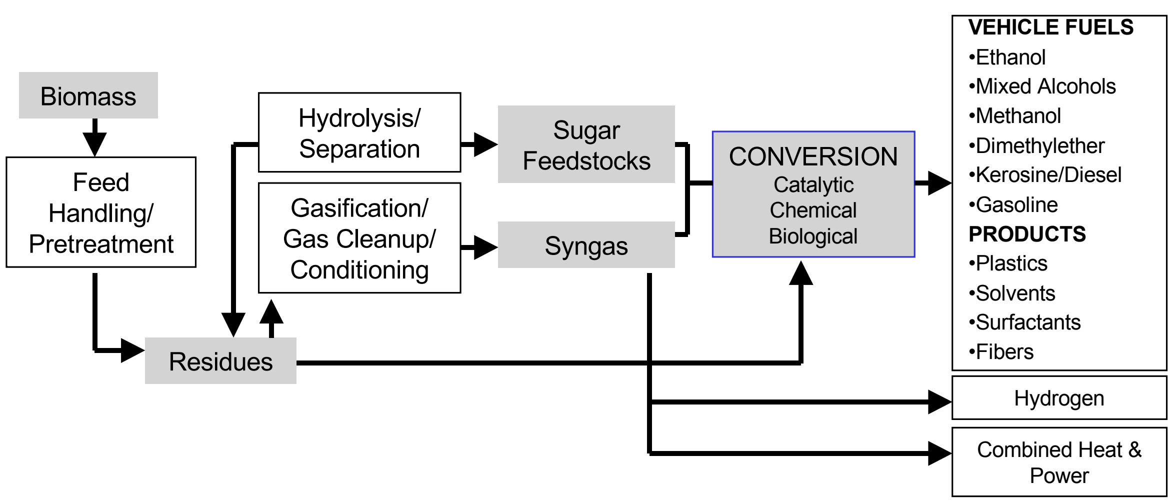

Figure 3-4 Utilization of Biomass to Produce Fuels, Products, Heat and Power

3.4.2 Status of Utilization Technology

Fuels and chemicals from sugars - The biorefinery concept is beginning to be successful in the U.S. agricultural and forest products industries, where such facilities now produce food, feed, fiber, fuels, and/or chemicals. Corn wet and dry milling plants, for example, are biorefineries that produce enzymes, lactic and citric acids, amino acids, other chemicals, and fuel ethanol from corn. The primary market for these products is the food and feed industries. These same mills also currently produce over two billion gallons of fuel ethanol per year.

Pulp and paper mills are operating biorefineries where wood is converted into pulp for papermaking, and the byproducts are used to produce chemicals, fibers and plastics such as cellophane. Byproduct fuels are used in on-site cogeneration systems to meet a large share of electricity and steam demand.

Technological advances are beginning to reduce the cost of producing industrial products and fuels from biomass, making them more competitive with those produced from petroleum-based hydrocarbons. As a result, industry is making new investments in the manufacture of biofuels and bioproducts.

In the chemicals and food processing industries, companies are working together to develop new technology for cost-effective production of plastics and chemicals from biomass. Strategic partnerships between the chemical industry, food, textiles and agricultural sectors are expected to become the mainstay of the emerging bioproducts industry and foster its growth over the next two decades.

Syngas conversion - The petroleum and petrochemical industries have developed first generation commercial catalytic processes for conversion of fossil-based syngas to fuels and chemicals. Examples include methanol-to-gas, methanol synthesis, ethanol via modified Fischer-Tropsch synthesis, mixed alcohol synthesis, hydrocarbon fuels, and hydrogen. The source of syngas for these processes is primarily steam reforming of natural gas, but naphtha reforming and coal gasification are also used.

3.4.3 Technical Barriers to Utilization of Platform Outputs

Achieving cost and performance competitiveness with fossil-based products is a key challenge that must be met by biorefinery industry. There are also technical barriers associated with biological and chemical processes for converting sugars and syngas to fuels and products, as well as integrating bioprocessing systems (see Table 3-5).

Cost and performance competitiveness - Petrochemical-based products dominate today's economy because of the low cost of fossil feedstock and the high conversion yields achievable through mature processes. Biomass-based products can compete via lower-cost feedstock, improved conversion, or high performance that adds value when compared with petroleum counterparts. However, the lack of understanding of life cycle performance and cost relationships in biomass-based products remains a major gap. Petroleum feedstocks have been studied for over 50 years, but a similar understanding of biomass-based materials does not exist.

Fermentation organisms - Organisms exist today that have been genetically engineered to ferment the key five and six carbon sugars found in biomass, but significant research challenges remain. The availability of biocatalytic organisms for producing ethanol and other chemicals remains deficient when compared with petrochemical catalysts.

Catalysis - The development of catalysts for converting sugars into higher value products is in its infancy when compared to today's petrochemical counterparts. Significant fundamental research is needed to support development of new catalysts for biomass.

E**fficiency of syngas conversion** - There are areas of fuels chemistry that require additional investigation to support a commercial demonstration program for biomass-derived syngas conversion. Catalyst selectivity and product yield remain as barriers to future commercial growth.

Process integration - Integration of fermentation and catalytic processes faces the challenges above as well as the issue of separations. Most fermentation products contain impurities such as protein, amino acids, which can lead to rapid catalyst deactivation. Methods for improving catalyst lifetimes via improved catalyst or purification methods will need to be developed to ensure cost-effective separation of product streams.

Mill integration - Integration of a gasifier system into an operating commercial-scale biorefinery is yet another technical hurdle which must be solved. To ensure that these facilities have sustainable operating economics, it is essential that the positive impacts of gasification are realized to their fullest potential and that negatives are minimized. For example, the biomass and black liquor demonstration projects at operating pulp mills will seek to maximize the positive upstream impacts on pulp quality and yield while minimizing downstream impacts on the causticizing load to the lime kiln.

Table 3-5 Technical Barriers to Utilization of Platform Outputs.

Processing Area	Barrier
Fermentation	• lack of tools for developing future generations of fermentation microorganisms • organisms with the facility to handle all five biomass sugars at relevant process conditions • robustness of microbes for demanding industrial conditions of low pH and high temperature • inadequate tolerance of organisms to high product concentrations, especially for solvents such as acetone, butanol and ethanol • cost-effectiveness of enzymatic conversion systems
Catalytic Conversion of Sugars	• lack of homogeneous and heterogeneous chemical catalysts for conversion of biomass feedstock into chemicals and fuels • limited understanding and use of thermochemical processing systems • lack of understanding of how reactions take place in the aqueous phase • insufficient understanding of the basic mechanisms of reaction pathways, adsorption, desorption, mass and heat transfer, fouling • insufficient methods for the direct use of sugars as structural components • lack of new catalytic systems specific for sugar conversion • reaction systems appropriate for sugar streams of different purity
Syngas Conversion	• insufficient understanding of the formation and destruction of tars • impact of gasification catalysts • carbon conversion kinetics and contaminant fate and management
Analytical Tools	• lack of analytical tools for integrated process development unique to sugar conversion • limited understanding of how the variable chemical composition of feedstock impacts the integrated process
Diesel Biorefineries	• cost effective production of biodiesel • insufficient performance data on biodiesel fuels • inadequate technology for yield value from all components of biomass oil processing systems
Process Integration	• inadequate validation of different scales of gasifier systems • difficult separation processes • impurities that can cause rapid catalyst deactivation • lack of methods for improving catalyst lifetimes in aqueous systems
Mill Integration	• increased causticizing load in pulp mills

3.4.4 Programmatic Objectives for Utilization Technologies

The Programmatic Objectives for the Utilization of Platform Outputs are to:

Verify fermentation and catalytic conversion for production of new fuels and bioproducts;

Verify commercial production of ethanol and other products from sugars derived from lignocellulosic biomass; and

Verify operation of the syngas platform with downstream processes for fuels/chemicals production and production of heat and power from turbines and fuel cells.

This MYPP will result in the following Outcomes under these objectives (from 2.3.2):

A complete analysis of biorefinery options by 2004 that identifies the most promising processes, products. This will then form the primary emphasis of the program.

Demonstrate an integrated process for fuels production from biomass at an appropriate scale by 2005.

Help U.S. industry to establish the first large-scale sugar biorefinery based on agricultural residues by 2010.

3.4.5 Technical Plan for Utilization

Utilization focuses on the utilization and conversion of sugars and syngas and is comprised of activities of both subprograms, Advance R&D and Systems Integration. The Plan for Utilization is structured to reflect those two subprograms.

3.4.5.1 Advanced R&D

OBP conducts advanced R&D to enable the cost-effective conversion of sugars and syngas to fuels and value-added chemical products. Existing corn grain processors will serve as the test beds for new technologies that convert glucose to value-added chemicals. OBP efforts leverage the billions of dollars already invested by the chemical and petroleum industries in syngas conversion.

Fermentation - Research will create a suite of biotechnology tools to enable the development of fermentation microorganisms that can utilize all five biomass sugars. Specific activities will improve metabolomics and other "omics" that will lead to improved microbial systems.

Partners in fermentation R&D include USDA, NREL, universities, biotechnology companies, the Corn Refiners and the National Corn Growers Association, and Cargill Dow. As part of this activity OBP will work to forge a relationship with the Office of Science "Genomes to Life" program.

This research will increase ethanol yields through the full use of carbohydrates from residues such as corn fiber. It will also yield organisms suitable for fermenting biomass sugars in streams with a range of purity and process conditions (high temperature, salts, inhibitors, etc.).

Catalytic Conversion of Sugars - Research explores new catalytic systems for producing value-added products from sugars. Activities include development of higher selectivity catalysts for aqueous systems, and investigation of new platform chemical or hybrid chemical/biological systems.

Research participants include national labs, universities, USDA, biomass processing companies (corn wet millers and pulp and paper operations), small businesses, and State agencies. The optimum result will be a suite of catalysts suitable for a range of processing conditions, and new, flexible chemical platforms that are suitable for a diversity of applications.

Syngas conversion - The OBP is conducting advanced R&D to improve the selectivity, yield and longevity of syngas conversion catalysts, and is examining the use of catalytic micro-channel reactors for conversion of syngas to fuels and chemicals. Research is being conducted in parallel to ensure effective integration of gas cleanup systems with catalytic conversion reactors. Several national laboratories (NREL, PNNL) and other DOE laboratories with expertise in gas-phase heterogeneous catalysis are working with industry partners on this effort.

3.4.5.2 Systems Integration

Systems integration activities for utilization are focused on technology validation, implementation, and development of the analytical tools needed to successfully integrate new technology.

Validation/verification of technology - Validation and verification of newly developed technologies is essential to creating a biorefinery. Through cost-shared partnerships, the OBP fosters opportunities for industrial facilities to implement new technology. The OBP provides technical resources through its National Bioenergy Center to facilitate this process. Some activities fall under the EPA Environmental Technology Verification program that provides 3rd party verification of technology classes.

OBP is conducting performance validation for different scales of gasifiers (biomass and black liquor), from small modular to large scale industrial systems. The national laboratories provide technical support for these activities, working with USDA, state and local governments, rural communities, and industrial partners to evaluate operating performance and demonstrate viability. These activities provide solid technical and economic data to justify implementation of gasifier technology in a variety of settings, and quantify the potential for improving local economies.

Black Liquor Gasification

The forest products industry generates more than 1.5 quadrillion Btu (55% of its total energy use) from biomass, including "black liquor" from pulping processes and bark and wood residues. Current practice is to burn the black liquor in Tomlinson recovery boilers (recovers pulping chemicals and burns organic matter).

Gasification of the black liquor and wastes coupled with gas turbine combined cycle power generation offers overall thermal efficiency increases of up to 10% and two times more power output per ton burned. With annual production of about 140 million tons of black liquor and biomass wastes, gasification offers an important biomass energy opportunity. By gasifying, rather than combusting, biomass wastes, the forest products industry can become a major producer of biomass-derived syngas and a net energy *exporter* selling excess "green power" to the national electric grid. Other advantages include increased pulp yield and quality, fewer air emissions, improved plant

Mill-scale validation activities are planned for a large black liquor steam reforming gasification system in Big Island, Vermont, and another large biomass gasification system in Louisiana. Georgia-Pacific, Boise-Cascade, Gas Technology Institute (GTI), MTCI, several national laboratories (NETL, ANL, ORNL), universities, A&E firms, and equipment suppliers are participating. The outcome will be two or more operating commercial-scale black liquor and biomass gasifiers with validated performance to support implementation in future biorefineries.

Analytical tools - Research will be conducted to develop tools and methods for integrated process development that are uniquely applicable to production of sugars from biomass. Specific areas of interest include improving methods for chemical analysis of biomass, validated material and energy balances for integrated technology, and improved engineering and cost analysis models to support decision-making. Tool and data development and validation will be conducted by NREL, universities, instrument suppliers, and engineering companies.

NREL, USDA and crop seed companies will also work to collect, analyze and evaluate genetically diverse feedstock samples grown under a wide range of environmental conditions. This will allow correlation between feedstock characteristics and process parameters such as sugar yield and enzyme digestibility.

These activities will produce new, rapid chemical analysis and on-line methods for biomass feedstock and process intermediates. Technical data from integrated pilot scale operations will be incorporated into process models to better predict performance and cost of production, helping to decrease uncertainty and risk in new sugar production technologies.

Diesel biorefineries - Integration efforts focus on cost-effective production of biodiesel, evaluating performance of biodiesel fuels, and seeking ways to optimize profitability in the diesel biorefinery. Research will explore new biomass oil platforms for producing fuels and chemicals and obtaining value-added products from glycerin or fatty-acid residues (byproducts of biodiesel production). Partners include the United Soybean Board (USB), NREL, chemical and petrochemical companies, engine manufacturers state and regional biomass offices. This effort will identify opportunities for producing new products from biomass-derived oils, and uses of the byproducts from biodiesel manufacturing.

Work is also ongoing to evaluate the performance of biodiesel in advanced and future diesel engines. Engine manufacturers and fleet users in federal and state agencies are working with NREL to develop performance data that can be used to establish the viability of biodiesel.

Combined Heat and Power (CHP) - Biorefineries currently combust biomass residues in steam boilers. However, the gasification combined cycle (a gasifier coupled to a gas turbine combined cycle or "GCC") offers much greater efficiency for converting residues to electricity (up to twice that of combustion/ steam) while producing steam from the gas turbine waste heat.

The OBP is conducting a number of activities to implement advanced CHP systems in biorefineries. Efforts are underway to identify opportunities for biomass CHP and syngas systems in existing chemical plants, and evaluate biomass processing residues for heat and power potential. Partners include engine and microturbine companies, national laboratories (NREL, ORNL, PNNL, NETL), fuel cell manufacturers, the Solid-State Energy Conversion Alliance, and the chemical industry. Through these activities the OBP hopes to ultimately map currently available feedstock with potential industrial CHP locations, and evaluate integrated gasifier systems for a wide range of feedstock.

The OBP is also evaluating the effects of syngas on gas turbine performance and operation to establish the feasibility of using syngas in a combined cycle configuration. NETL, other DOE laboratories and equipment suppliers will be participating in this effort. The program will apply the lessons learned and technology knowledge gained from the intensive EERE Biopower Program and EERE Forest Products Industry gasification efforts of the1990s to enable commercial availability of medium heat-content gasifiers suitable for biorefinery use.

3.4.5.3 Integrated Biorefinery and Product Development

In 2002 the OBP awarded funds to six major biorefinery development projects that are focused on new technologies for integrating the production of biomass-derived fuels and other products in a single facility. The emphasis is on using new or improved processes to derive products such as ethanol, 1,3 propandiol, polylactic acid, isosorbide, and various other chemicals. A synopsis of these projects is given in Table 3-6. Milestones for these projects will be developed over the next year.

A number of projects are already underway to develop technologies for entirely new industrial bioproducts from corn-derived sugars, sorghum, and vegetable oils. The activities conducted range from fundamental research on feedstock-specific catalysts to integration of new technology into the biorefinery. Products are diverse, ranging from corn- and oil-based polymers to chemicals such as malonic acid and isosorbide. Partners include national laboratories (NREL, ORNL, PNNL, SNL), individual chemicals, food and enzyme manufacturers, universities, and trade associations such as the Iowa Corn Promotion Board, United Soybean Board, and the National Corn Growers Association.

Table 3-6 Integrated Biorefinery Projects

2nd Generation Dry Mill Biorefinery - Broin and Associates, Inc. of South Dakota will enhance the economics of existing ethanol dry mills by increasing ethanol yields and creating additional co-products. Broin estimates that its process will increase ethanol output at existing plants by approximately 10-20% by 2006.

New Biorefinery Platform Intermediate - Cargill, Inc. of Minnesota will develop a bio-based technology to produce a wide variety of products based on 3-HP acid, which is produced by the fermentation of carbohydrates.

Integrated Corn-based Bio Refinery (ICBR) - Delaware's E.I. du Pont de Nemours & Co., Inc. (DuPont) will build a bio-based production facility to convert corn and stover into fermentable sugars for production of value-added chemicals.

Making Industrial Bio-refining Happen - Based in Minnesota, Cargill Dow LLC National will develop and validate process technology and sustainable agricultural systems to economically produce sugars and chemicals such as lactic acid and ethanol.

Advanced Biorefining of Distiller's Grain and Corn Stover Blends - High Plains Corporation, with plants in Kansas, Nebraska and New Mexico, will develop a novel biomass technology to utilize distiller's grain and corn stover blends to achieve significantly higher ethanol yields while maintaining the protein feed value.

Separation of Corn Fiber and Conversion to Fuels and Chemicals - The National Corn Growers Association, based in Missouri, will develop an integrated process for recovery of the hemicellulose, protein, and oil components from corn fiber for conversion into value-added products.

3.4.6 Key Milestones for Utilization Technologies

Key milestones for Utilization Technologies are shown in Table 3.6.

Table 3.6 Milestones for Utilization Technologies

Processing Area	FY 03-04	FY 04-05	FY 06-10
Advanced Biomass R&D			
Fermentation Microorganisms	• Develop a recombinant *S. cerevisiae* with improved capability to use L-arabinose from corn fiber hydrolysate (CRA/NCGA)	• Develop a xylose fermenting yeast (CD).	
Catalytic Conversion of Sugars	• Complete analysis of top chemical products that could be produced from biomass • Identify general and common technical barriers to producing these top chemical candidates		
Syngas Conversion	• Results obtained from the evaluation of potential catalysts on authentic biomass-derived syngas streams	• Completion of catalyst evaluation unit suitable for integration with syngas production systems	
Systems Integration			
Process Integration/ Technology Validation	• Validation of FERCO Silvagas™ gasifier, Vermont • Validation of small modular rural energy systems • Start-up of 200 tpd sodium carbonate black liquor low-temperature steam reforming gasification validation (Big Island, VA) • Go/no-go decision on DeRidder, LA biomass gasification project	• Validation of Chariton Valley Biomass project	• Gas turbine start-up for biomass GCC, low and high temperature gasifiers • Start-up of 100 tpd biomass gasification validation project (DeRidder, LA)
Analytical Tools	• Near infrared rapid on-line chemical analysis of biomass feedstock, pretreated materials and products demonstrated at pilot scale • Confirm overall material balance closure at 95%. • Estimates of the potential variability in the chemical composition of corn stover feedstock and economic impacts	• Models developed from pilot plant data according to standard process industry principles and publically available (ongoing)	• Transfer advanced analytical methods and calibration models to biorefinery partners.
Diesel Biorefineries	• Comprehensive report describing R&D opportunities for products from fatty acids and glycerin to help guide future platform R&D • Performance testing in EGR engines		
Combined Heat and Power	• Evaluate integrated biomass gasifier-SOFC systems for various feedstock. • Evaluate syngas for combined cycle turbines.	• Map of available feedstock relative to potential industrial CHP sites	

3.5 Sustainable Feedstock Technologies

3.5.1 Background on Sustainable Feedstock Technologies

Biomass feedstocks are already supplying about 3 quadrillion Btus (Quads) to the Nation's energy supply based primarily on wood residues. The potential exists for increasing total biomass contribution up to 10 Quads nationwide. However, biorefinery developers require assured amounts of feedstock of desired quality on a year-round basis at specific locations.

Existing industries that already have a biomass supply infrastructure – such as corn wet and dry mills, and pulp and paper mills - can mitigate the issues of acquiring new feedstock supplies by more fully utilizing all components of the wood and grain residues. For new biorefineries, however, region-specific feedstock technologies and infrastructure will be needed to assure a steady supply of low-cost biomass with the desired quality. Components of a feedstock supply system are shown in Figure 3-2.

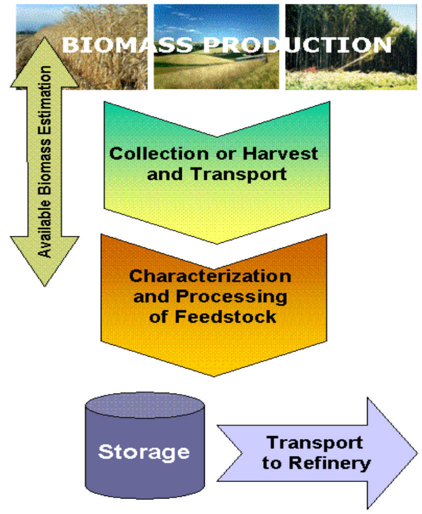

Figure 3-2 Key Feedstock Supply Components

3.5.2 Status of Sustainable Feedstock Technologies

Agricultural crops and residues are the largest potential new biorefinery feedstock resource. Current production is concentrated in the Midwest and Great Plains. Grain collection and supply infrastructure for the production of ethanol is a mature technology. The crop residues currently returned to the soil could be an additional revenue source for farmers. Limited research is ongoing to identify those conditions where residues could be removed yet maintain soil nutrient status and texture.

Wood residues generated by the forest products industry, including logging residues, bark and other mill residues and spent pulping liquors, are the source of about 2.5 quads of energy today. The forest products industry has in place an existing wood harvesting and preparation infrastructure for wood fiber that is already capitalized and operating. Wood residue collection could be expanded under the right ecological, financial and policy conditions with collection of more logging residues and with thinning of dense undergrowth creating fire hazard conditions. This industry adheres to a set of sustainable forestry principles that integrates the practices of reforestation, nurturing, and harvesting of trees with the conservation of soil, air and water resources, wildlife and fish habitat, and forest aesthetic values. Urban wood residues from tree trimmings and construction and demolition activities contributes about 0.4 quads of energy. This wood tends to currently be used only where tipping fees are high.

Plants such as grasses are already widely planted for land conservation purposes and forage. New varieties with a capability for sustained high biomass yields have been developed. The deep roots, perennial nature, and low nutrient demands of switchgrass and other grasses offer potential for a sustainable feedstock supply system.

Short-rotation trees have been established commercially for fiber and in a few locations as dedicated energy crops for demonstration projects as a result of previous DOE research and technology transfer. New varieties and culture techniques offer the capability for high yield, sustainable production systems similar to grasses.

The current focus of OBP research will be on agricultural crops and residues with the assumption that energy crops such as grasses and short-rotation trees will be developed by USDA or others. Work in basic plant sciences to improve
existing and alternative energy crops will

primarily be conducted by USDA, the DOE Office of Science, the National Science Foundation (NSF) or other groups.

3.5.3 Technical Barriers to Sustainable Feedstock Technologies

Technical barriers that pose a challenge to developing biorefineries with a sustainable feedstock infrastructure based primarily on agricultural residues are shown in Table 3-7.

Resource availability uncertainty - Major constraints to developing biorefinery facilities are lack of information and uncertainty about amount, price, quality, and year-round reliability of residue feedstocks at any given location and the need for long-term fuel supply contracts. Better information on both resource and market factors is needed to reduce uncertainty.

Biomass variability - The characteristics of biomass can vary widely in terms of physical and chemical composition, size, shape, moisture content, and bulk densities. These variations can make it difficult (or costly) to supply biorefineries with feedstocks of consistent quality year-round.

Sustainability requirements - Successful biorefinery enterprises must be based on sustainable feedstock supplies and life cycle benefits compared to fossil fuel use. Collection of agricultural residues risk the loss of long-term crop productivity and reduction of soil carbon levels unless done wisely based on knowledge of removal effects.

Engineering supply systems - These are relatively mature for the forest products industry and for crops used in food production or existing biorefineries (corn grain). Agricultural residues create engineering supply system challenges because of their low bulk density and low tons/acre yield. This requires new systems for cost-effective feedstock collection, transportation, and handling. The short harvest window for agricultural residues requires year-round storage with associated fire and health hazards and deterioration risks.

Table 3-7 Technical Barriers to Sustainable Feedstock Technologies

Technical Area	Barrier
Resource Availability	• lack of credible data on price, location, quantity, and quality of biomass • need for long-term fuel supply agreements
Biomass Variability	• local variation in types and amounts of biomass available • wide variations in physical and chemical composition, size, shape, moisture content, bulk densities of un-treated biomass
Sustainability Requirements	• potential loss in crop productivity, soil health and carbon levels with excessive residue removal-life cycle effects • insufficient information to predict environmental effects of residue removal as function of soil type, climate, management scenario and harvest techniques
Engineering Systems	• handling and transportation challenges due to low bulk-density of biomass • inability to monitor fluctuations in feedstock properties • lack of robust feed preparation and handling systems • cost-effective collection and transport difficult due to low residue tons/acre • storage costs and risks due to short crop residue harvest window

3.5.4 Programmatic Objectives for Sustainable Feedstock Technologies

The Programmatic Objectives for sustainable feedstock technologies is to:

D*evelop information, tools and sustainable, technology to facilitate the use of renewable biomass resources for producing clean, affordable, and domestically produced fuels, chemicals and power.*

3.5.5 Technical Plan for Sustainable Feedstock Technologies

A customer-driven roadmap for sustainable feedstock technology development will be produced in FY 2003 through the joint efforts of feedstock research leaders at Idaho National

Engineering & Environmental Laboratory(INEEL), Oak Ridge National Laboratory(ORNL), Department of Energy and USDA biomass staff, and key industry and producer stakeholders. This roadmap will greatly influence the details of the research agenda for the next 5 years particularly in the sustainability and engineering systems area. However, major expected activities and outcomes are as follows:

Resource availability assessment- To address uncertainties in biomass feedstock availability and biomass markets, activities will be conducted to develop high quality, credible, accessible information on the location, price, quantity, and quality of all types of biomass resources in the U.S. based on crop and forest data, sustainability constraints, and supply logistics. Included in this effort is the development of modeling tools that predict potential location, price, and quantity of new biomass crops that consider competitive demands for biomass resources. National laboratories will work with universities, USDA research and policy analysis groups, and consultants to develop accurate data. Laboratory staff will work on specific projects to assist in developing frameworks for long-term fuel supply contracts.

The information developed will increase confidence in the availability of an adequate biomass resource base for biorefineries. Planners and policymakers at local, state and national levels will use the data for market analysis and policy development, to establish biomass program metrics, and for preliminary siting considerations by biomass project developers.

Biomass variability - To address the challenge of variability in feedstock characteristics, OBP will support a systematic collection of information on feedstock characteristics as a function of resource type, location, harvesting technology, and management conditions. Research will be conducted to develop cost-effective methods to control and modify physical characteristics (e.g. grinding, drying and densification), and to evaluate the feasibility of homogenizing feedstocks to create consistent quality. Collaboration with biorefinery users will help to establish quality criteria and the control procedures required to ensure that feedstock pre-treatments produce the uniformity and quality needed by biorefiners. This research and development will be a concerted effort of ORNL, INEEL, USDA research groups, universities, farmers, and equipment manufacturers.

The outcome will be integration of existing or required feedstock supply systems with feedstock quality requirements for a wide variety of biorefinery operations. Potential technology advances include pre-processing and densification to reduce physical variability, homogenization to reduce chemical variability, and improved storage systems and quality control procedures to facilitate year-round feedstock uniformity.

Sustainability requirements - OBP will work with USDA to create a plan for developing the data needed to demonstrate the sustainability of the biomass resource. This will include the data needed to evaluate the environmental effects of crop residue removal on sustainability (crop productivity, soil health). Data will also be developed to quantify the potential regional environmental benefits of large-scale biomass production, harvesting and collection (e.g., watershed protection, carbon sequestration). Partners in sustainability research and life cycle analysis include ORNL, INEEL, NREL, USDA research groups, universities, farmers and biorefinery developers.

The outcome of this research will be credible data and information for determining where biomass can be sustainably collected or produced for bioindustry operations. It will also provide input to life cycle analysis and resource assessments to determine where sustainably collectable amounts are sufficient for supporting a bioindustry. Regulators will find the data useful for evaluating or modifying land management regulations, and farmers can use the data and recommendations to improve crop sustainability.

Engineering supply systems - This activity will involve detailed engineering evaluation of the existing collection, handling and transport equipment in terms of operational performance, capacity, and reliability. National laboratories will collaborate with equipment manufacturers to design and test innovative collection, handling, and transport equipment. Research will focus on developing a one-step harvesting systems with crop component separation capability. The near-term emphasis will be on agricultural residues, primarily corn stover and small grains. The overall objective is to reduce the current costs of agricultural residue collection, pre-processing, storage and transport systems and producing higher quality feedstock. OBP partners will also develop a supply logistics system model useful for techno-economic analysis and supply systems optimization.

Storage and transport issues will be addressed by evaluating and developing moisture control and densification technologies most appropriate for the types of biorefinery systems being developed and the regions where they will be implemented.

In the near term, proposed operational modifications could reduce delivered costs by 10 to 20 percent, compared to baseline estimates. In longer-term, new equipment and systems will either further reduce delivered feedstock costs or will produce higher quality feedstock that helps reduce cost of the final biomass product. Another outcome will be improved profitability of feedstock producers, supplier cooperatives, and/or feedstock brokers through the use of improved equipment, storage methods, and transport systems.

3.5.5 Key Milestones for Sustainable Feedstock Technologies

Key milestones for sustainable feedstock are shown in Table 3-8.

Table 3-8. Milestones for Sustainable Feedstock Technologies

Barrier	FY 03-04	FY 04-05	FY 06-10
Resource Availability	• Web accessible price/supply information on biomass resources for all major resource categories. • Assumptions in assessments and models are well documented and public	• Updates to price/supply information are made as economic or policy conditions or yield and technology assumptions change.	
Feedstock Variability	• Databases and models describing feedstock characteristics as a function of resource type, location, harvesting technology, and management conditions • Develop Roadmap for reducing variability.	• Data on costs and energy requirements of various handling and pre-processing techniques to minimize variability	
Sustainability	• Papers and data bases containing descriptions of potential environmental effects under given conditions • Develop roadmap for improving sustainability	• Recommendations on crop or soil management techniques for sustainable collection or production of biomass	
Engineering Supply Systems	• Develop a systems engineering plan for one-pass harvesting, in collaboration with industry and stakeholders. •Publication of information detailing performance and reliability of the existing equipment used for biomass harvesting & collection. •Develop roadmap for Engineering Supply Systems.	• Demonstrate a cost-effective system for one-step harvesting of agricultural resides • Data on costs of alternative storage and transport methods for various feedstock types • Supply logistics optimization model available to industry • Recommendations for improved supply logistics and infrastructure for biorefinery projects and equipment manufacturers	

4.0 Implementation Strategy

4.1 Program Strategy

The OBP implementation strategy is: To utilize partnerships with industry, industry associations, academia, national laboratories, non-government organizations, and other federal agencies and state agencies. The strategy benefits from the complementary strengths of the partners and from the framework provided by the Biomass R&D Act of 2000 (the Act) and its reauthorization in 2002 under the Farm Bill (P.L. 107-424).

The key tenets of the implementation strategy are to

- Develop and validate advanced technologies for more efficient and profitable multi-product biorefineries using the existing industrial base (e.g., corn grain and forest products biorefineries).
- Verify integration of advanced technologies with existing and new facilities, thus decreasing technical and financial risks, facilitating new technology deployment and gaining operational experience.
- Annually assess progress of technology development and systems integration with consistent management tools. The Stage Gate process will be used for making decisions about R&D that lead to process and/or product development efforts.
- Assess the life-cycle, environmental and economic performance of biobased products, biofuels, and heat/power resulting from integrated systems.
- Use competitive processes for selection of performers whenever possible while maintaining a focused core of activities at the national laboratories.

4.2 Mechanisms for Program Implementation

To achieve its goal (section 2.3), OBP utilizes a three-pronged research arm comprised of national laboratories and universities; industry; and other federal, state and local agencies. OBP funds it RD&D through two broad categories of funding mechanisms: competitive solicitations, and sole-source/non-competitive. Noncompetitive funding is only used when necessary (e.g. earmarks). In both cases the funding vehicles used are: cooperative agreements (generally used with industry and universities); GOCO contracts or CRADAs (used with national laboratories); and/or Interagency agreements and grants (used with Federal and State agencies).

R&D funded by OBP decreases the technical and financial risk of developing and commercializing conversion technologies and addresses integration issues between feedstock production/ collection, handling, and transportation to conversion facilities. Industry cost share varies from 20 -50 percent for these activities, in line with the Energy Policy Act of 1992.

To create an integrated bioenergy industry, OBP funds Systems Integration activities to **validate and verify** newly developed technologies. Additionally, OBP provides technical resources (available to its partners) through its National Bioenergy Center for these activities.

Advanced R&D and Systems Integration efforts with various crop-grains, woods, grasses and residues expand the product slate and increase future economic viability in cooperation with industry. These activities help gain **operational experience** of multi-product capabilities in the existing industrial base – such as corn/grain and forest products refineries.

Both Advanced R&D and Systems Integration activities in biomass gasification technologies (biomass and black liquor) are geared to provide national energy, environmental, and safety benefits as well as increase the technical performance of commercial-scale integrated gasifier systems.

4.3 Government/Industry Coordination

The Biomass Act of 2000 created the Biomass R&D Technical Advisory Committee, an advisory group to the Secretaries of Energy and Agriculture. The Committee includes 30 industrial experts, advises DOE/OBP on its technical focus and reviews and evaluates proposals. The Committee also facilitates partnerships among Federal and State agencies, producers, consumers, the research community, and other interested groups.

Industry groups are formally organized to provide input on key areas and gaps. For forest products, the American Forest and Paper Associations prepared the Agenda 2020 vision and technology roadmaps. The Biomass Interest Group , a consortia of electric utility companies and technology developers led by the Electric Power Research Institute, provides a mechanism for feedback and interactions among developers and users. The chemical industry is engaged via their Vision 2020 group and industrial roadmaps. Farm communities, their trade associations, and other interested industries are also engaged regularly.

4.4 Inter- and Intra-agency Coordination

DOE uses its major strengths in advanced technology development, systems integration, and specialized science and technology capabilities and facilities to work in partnership with other DOE offices and various federal and state agencies (see Figure 4-1).

4.4.1 Interagency Coordination

The Biomass Act created the Biomass R&D Board (the Board) which is responsible for coordinating biomass activities across Federal agencies. This cabinet level board coordinates biomass R&D performed by the major Federal sponsors (DOE and USDA) and other relevant agencies (EPA, NSF, DOC/NIST, DOI/BLM, among others).

The Board coordinates programs within the Federal Government for the purpose of promoting the use of biomass. With its strategic planning, the Board seeks to guide the activities of various participating agencies in terms of Federal grants, loans, and assistance.

4.4.2 Interagency Interactions

OBP works closely with USDA in a number of ways. The technology base for products and energy within the USDA is provided by the USDA/ Agriculture Research Service (ARS) through programs conducted at the five USDA Regional Agricultural Utilization Laboratories and their partners. Similarly, the USDA/Forest Service has the Forest Products laboratories to address use and resource conservation, including forest management. Science for soil and water conservation is provided by USDA Soil Conservation laboratories. Other offices support technology transfer and deployment (see Sections 4.6 and 4.7).

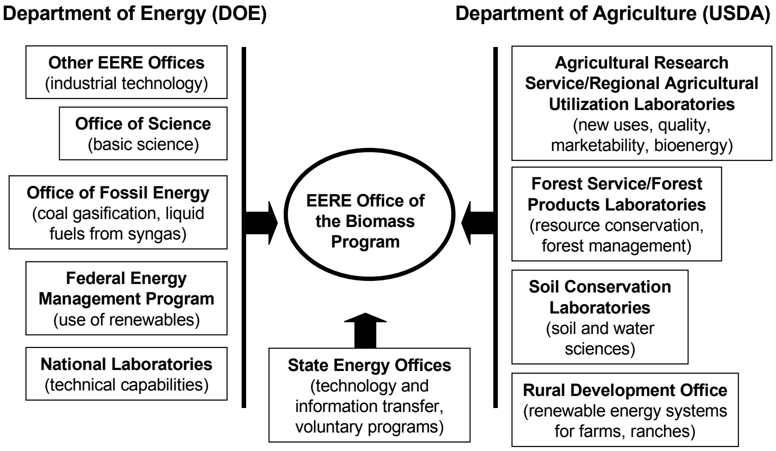

Figure 4-1 Inter- and Intra-Agency Coordination

Examples of interactions among agencies are illustrated in Figure 4-2. Other programs include:

- Energy Audit and Renewable Energy Development Program for entities to administer energy audits and renewable energy development assessments for farmers, ranchers and rural small businesses (led by USDA Rural Development)
- Renewable Energy Systems and Energy Efficiency Improvements for loans, loan guarantees and grants to assist eligible farmers, ranchers and rural small businesses. (Led by USDA Rural Development/Rural Business-Cooperative Service).

4.4.3 Intra-agency Interactions

Intra-agency interactions include other EERE Offices (Office of Industrial Technology, Hydrogen, Power, States Energy Office, Federal Energy Management Program-FEMP). OBP actively participates in the FEMP Biomass Deployment program - Buy Bio. The EERE State Energy Program (SEP) provides support to communities and states to extend energy-efficiency technologies and practices. SEP RD&D awards for biofuels, biopower and bioproducts serve to augment the OBP portfolio.

The OBP also interacts with the DOE Office of Science, and Office of Fossil Energy (FE). FE involvement in coal gasification and liquid fuels from syngas provide a basis for interactions with OBP. OBP also takes advantage of co-funding opportunities through other DOE initiatives such as Small Business Innovation Research (SBIR) and the science initiative.

4.5 State and Regional Interaction

Figure 4.2 - Selected Examples of Interagency Interactions

- **Solicitations** - The Biomass R&D Initiative within the Farm Bill authorized USDA to spend $5M on bioenergy projects in FY02 and $14M annually for FY 2003 - 2007. USDA selected projects from the biorefinery selections made by DOE for the initial funding. Future joint solicitations are possible.
- **Joint research** - DOE laboratories, USDA Agricultural Research Centers and the Forest Products Laboratory are undertaking joint work under Interagency Agreements employing capabilities at each institution to accomplish biobased products, biofuels, or biopower research.
- **Forest management** - Stemming from a workshop on strategic federal laboratory partnerships, USDA is employing DOE/Industry-developed technology to assess the use of small modular biomass power systems to manage forest residues. The Forest Products Laboratory and DOE's National Bioenergy Center are jointly monitoring this work.

The OBP works with state and local governments and communities to integrate technologies and assess regional bioenergy opportunities. OBP also sponsors and participates in regional activities directed at expanding the bioindustry.

DOE/EERE Regional Offices are a resource that enables OBP to take advantage of opportunities at the state and local levels. The Regional Offices manage more than $200 million in grants for energy efficiency and renewable energy programs, and provide states with technical assistance on the use of Systems Benefit Charges (these can create funding for renewable energy). A strategy is currently being developed by OBP to expand interaction at the regional level and take advantage of the resources represented by the Regional Offices.

The OBP also plans to work with the Governors' Ethanol Coalition (GEC) to increase the use of ethanol fuels through various activities. This group, which was formed in 1991, now has 27 member states as well as international representatives from Brazil, Canada, Mexico and Sweden.

4.6 Universities

Universities provide a vital link to fundamental science and technology expertise. They also provide the critical foundation and setting for the development of a new set of engineers and scientists skilled in the disciplines necessary to build a bioindustry. A number of universities are partners in OBP activities, and participate via the same competitive mechanisms as industrial partners and universities.

4.7 Technology and Knowledge Transfer

The OBP has seven primary avenues for transferring technology and knowledge to U.S. industry:

- Cost-shared RD&D
- Interagency agreements (Federal)
- Interagency agreements (States)
- Cooperative Research and Development Agreements (CRADAs)
- Active participation in technical forums
- Web-sites
- International agreements and FIFA inquiries.

Cost-shared RD&D is initiated via competitive, and non-competitive solicitations. It is the preferred method of RD&D and technology transfer because U.S. industry is closely involved from a technical and planning standpoint as well as a financial standpoint (the cost-share). This involvement is by design and usually ensures a genuine effort by U.S. industry to commercialize the technology. For example, the forest products Agenda 2020 activities in black liquor gasification are cost-shared activities with companies, academia, laboratories, and a variety of other entities.

DOE and other federal and state agencies negotiate interagency agreements as mechanisms to co-fund activities that are mutually beneficial to sets of stakeholders and help achieve the goals of individual agencies. Similarly, DOE and USDA laboratories have negotiated intellectual properties and joint agreements to promote interaction.

The preferred partnering mechanism between industry and DOE laboratories is the CRADA. The CRADA provides for intellectual property rights and patent waivers between DOE laboratories and industrial partners

OBP sponsors technical conferences and workshops on a variety of subjects to accelerate technology development and implementation.

Examples are the Bioenergy series of regional conferences and the Biotechnology for Fuels and Chemicals Symposia (rotated yearly between Colorado and Tennessee and organized by NREL and ORNL). A number of regional and state activities are also sponsored. The Regional Offices have considerable activities devoted to information dissemination for EERE programs, including the OBP.

Internationally, the OBP co-sponsors a World Biomass Conference with Canada and the European Union. Technical papers in peer reviewed journals, patents, conference proceedings, and presentations at professional meetings serve as venues for advertizing the technology developed by DOE. International collaboration occurs through International Energy Agency (IEA) activities in bioenergy (e.g., Short Rotation Crops for Bioenergy Systems; Conventional Forestry Systems for Sustainable Production of Bioenergy; Gasification of Biomass; Liquid Biofuels).

The OBP communicates technology development and other information to industry or customers through various outreach activities, including the Internet (http://www.bioproducts-bioenergy.gov) OBP's website provides information on new technologies, solicitations, publications, and legislative activities. It links with key USDA sites and other government and private sector activities, provides information on biomass activities sponsored by DOE, and characterizes the contribution of biomass to the economy.

To facilitate communications about program results and other OBP activities, the OBP annually develops an internal communications plan. This plan serves to guide outreach efforts and ensures that communications are effective and consistent.

4.8 Technology Deployment

The OBP supports efforts to validate and verify technology (using competitive solicitations). When funding allows, these include cost-shared deployment of pilot-scale, integrated systems. These activities reduce technical and financial risk and provide a strong basis for industrial commercialization and adoption.

The mechanisms used for technology transfer (e.g., CRADAs, cost-sharing) in general provide greater opportunities for deployment of technology by promoting and protecting industry's investment.

5.0 Management Plan

The (OBP) has the overall authority and responsibility for managing DOE research, development and demonstration activities relating to the use of renewable biomass for fuels, chemicals and power. In some cases, DOE field and operation offices as well as the national laboratories have responsibility for execution of contracts and other administrative actions.

The Office of the Biomass Program will provide the overall strategy, policy, management, direction, and programmatic expertise necessary for a balanced program of research, development, testing, and evaluation that will catalyze the establishment of biomass technologies. Further, the OBP will build its investment portfolio on detailed market and technology analysis, in collaborations with leaders and technology experts from industry, academia, and the national laboratories and in union with the other programs within EERE.

5.1 Program Management

The organizational structure providing R&D management for OBP is shown in Figure 5-1. The OBP is one of eleven programs residing within the Office of Energy Efficiency and Renewable Energy (EERE), and under the purview of the Assistant Secretary for EERE. Overall management responsibility for the program resides with the OBP Program Manager, who reports directly to the EERE Deputy Assistant Secretary (DAS) for Technology Development.

The OBP is responsible for the routine operations of the office, as well as formulating strategic and operational plans, justifying and allocating resources, establishing R&D and programmatic priorities and goals, and evaluating the performance of its programs. Management of the overall program includes consideration of the President's National Energy Policy, EERE's strategic plan and priorities, and the EERE strategic program review.

OBP implements agency policies and procedures, and reports on progress and activities to senior DOE organizational management. The office is also responsible for implementation of certain public laws (see Section 1-2). The Multiyear Program Plan and associated annual operating plans and communications plans provide the program management framework.

Corporate communications are managed by the EERE Communications Office. Contract management and budget execution support is provided through the EERE Deputy Assistant Secretary for Business Administration, and through DOE operations and field offices.

OBP contracts directly with the national laboratories, universities, and industry to conduct RD&D programs, and in rare cases, delegates contracting and project management authority to the national laboratories. Competitive solicitations are the primary vehicles for program implementation, although the national laboratories are funded directly for specific research activities depending on technical capabilities.

The national laboratories provide technical assistance in areas of expertise, and are also responsible for managing research activities. Overall program management is facilitated by annual peer review of the program and by the project level Stage Gate peer review. Guidance and evaluation is also sought from program reviews conducted through the National Academy of Science, National Research Center. Strategic planning occurs internally and is subject to review by appropriate panels.

5.2 Team Management Structure

The OBP has established teams which are responsible for management of technology RD&D and other administrative activities. These teams utilize the knowledge and skills of the OBP staff, and help guide the efforts needed for technology development through commercialization.

External personnel include partners in industry, national laboratories, and academia as well as those in the EERE regional and field offices. These external members leverage the limited headquarters personnel into a dynamic team all working towards the fulfilment of the program goals.

The team leaders are responsible for resource allocation in their research areas and delivery of the annual milestones. The team leaders are responsible for keeping the program manager informed of successes and problems and formulating options to maintain progress and schedule. Specific management responsibilities of these teams are shown in Table 5-1.

The OBP organization fosters effective partnerships with its stakeholders in the public and private sectors. In keeping with the President's Management Agenda, and the EERE Strategic Program Review, OBP has established a structure that focuses on program management and minimizes layers of authority, with the R&D goals as a centralizing theme. The respective capabilities of headquarters, field and operations offices, and national laboratories are utilized to optimize the strengths of these organizations and ensure the success of the program.

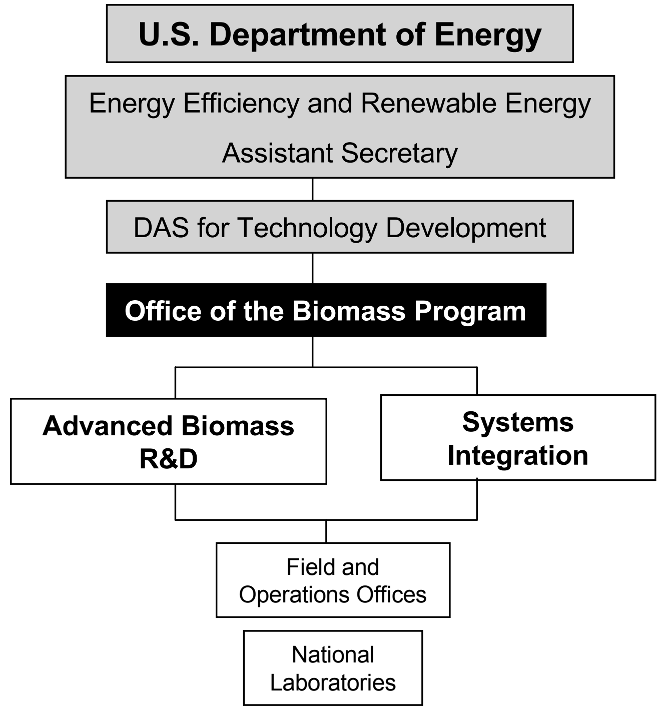

Figure 5-1 U.S. Department of Energy, Office of the Biomass Program Organization Structure

Table 5-1. OBP Management Teams and Responsibilities	
Advanced Biomass R&D	**Systems Integration**
• Manage fundamental R&D for the biomass to sugar and syngas platforms in accordance with the multi-year plan • Technology-specific economic, benefit, and sustainability analysis • Organize and chair detailed peer/scientific review of projects • Track and report milestones and financial information • Collaborate with the Federal R&D Board and other agencies to support the development of the Federal biomass R&D portfolio	• Management of validation and verification programs • Scale up engineering issues • Integration of process technologies into various systems • System level life-cycle, national benefits, and sustainability analysis • Manage the broad interface with the Biomass R&D Federal Advisory Committee, industry, academia, Federal agencies and other EERE programs • Lead the revisions to the multi-year plan • Build linkage to state and local efforts in biomass to broadly leverage the program's resources

Management authority for awarded tasks or program areas is assigned based on the capabilities and appropriateness of the organization for managing the work. The National Bioenergy Center including National Renewable Energy Laboratory (NREL) and Oak Ridge National Laboratory (ORNL), and the Pacific Northwest National Laboratory (PNNL), Idaho National Environmental and Energy Laboratory (INEEL), and the National Energy Technology Laboratory (NETL) are currently the primary federal laboratory partners with OBP in conducting and managing its RD&D programs.

5.3 Management Control and Coordination

Management control of funded activities is accomplished through a variety of mechanisms:

- Annual operating plans are developed for specific technical areas to provide details of work planned for the year and to establish measures for evaluating performance. Each plan includes milestones, schedules and cost projections along with specific performers of the research.
- Organizations conducting research must submit quarterly and annual progress reports outlining technical status, problems areas, achievements, and cost issues. Site reviews may be conducted as needed to assess obstacles and view the work in progress.
- Periodic Stage Gate reviews are conducted with field investigators, industry experts and program management.
- Project management is conducted by monitoring task schedules, milestones, labor and capital requirements, and projected costs over time. Invoiced costs are provided to OBP management on a monthly and quarterly basis to support project management activities.

The activities conducted within the OBP Advanced Biomass R&D and System Integration areas are coordinated to build on synergies and monitor efforts that are complementary, sequential, or being conducted in parallel. Coordination activities encompass:

- weekly office-wide staff meetings to discuss current issues, progress and achievements
- contractor review meetings to discuss progress and obstacles
- strategic planning meetings

Stage Gate Management Principles

Stage Gate management is a process for making disciplined, informed decisions about R&D that lead to focused process and/or product development efforts. As a project passes from one stage to the next, it moves to a higher level of spending. Decisions are made at each stage as to whether a project will pass through the "gate" to the next stage. The result is that projects with technical or market issues are weeded out earlier rather than later, and more funds are spent on projects with the greatest potential for success.

Stages include: preliminary and detailed investigations, exploratory research, development research, testing and validation, and commercial launch. The expected effect is to better integrate our R&D knowledge and successes with those of our partners and thereby bring science and technology to application sooner, at lower cost, and with improved probability of success. Stage Gate supports program portfolio development, alignment of R&D project and program objectives, guidance on project scope, quality, outputs and integration, and reviews projects to evaluate progress and fit in the OBP portfolio.

Coordination with other program offices is essential for the success of the biomass program and EERE in total. The team leaders are responsible for coordinating and leveraging R&D activities with the other EERE programs. This coordination is tracked and facilitated by the program manager.

Figure 5-2 illustrates the timing of management control and coordination activities throughout the year. These activities are scheduled to coincide with Congressional budget schedules, fiscal year start-end, and internal planning and project implementation factors.

5.4 Performance Measures

The progress of RD&D activities conducted by OBP will be measured by comparison with the programmatic technical goals and milestones set by this Multiyear plan (see Section 2).

Individual annual operating plans will also be used to measure success and provide performance indicators.

In addition, OBP annually conducts a detailed analysis of R&D to determine the projected benefits over the short and long term. This analysis looks at specific markets for fuels, chemicals and power, as well as the availability of feedstock and their impact on biomass technology deployment. The results of this analysis are used to respond to the Government Performance Reporting Act (GPRA), to predict the potential impacts of Federally-funded research, and to make realistic projections of market adoption.

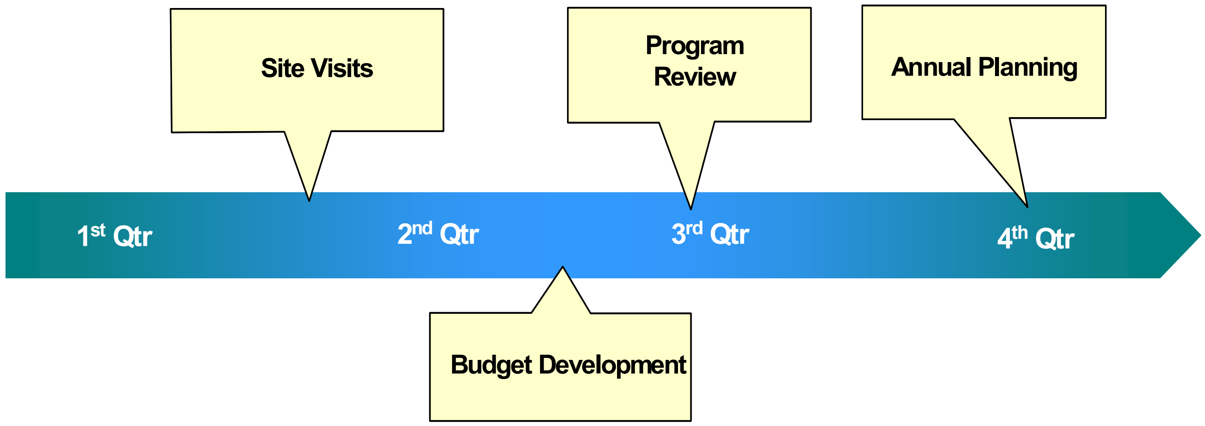

Figure 5-2. Anticipated Schedule of Program Management and Coordination Activities

For More Information on the Office of the Biomass Program

Office of the Biomass Program Official Website

http://www.bioproducts-bioenergy.gov/.

Information about the Biomass Technical Advisory Committee

http://www.bioproducts-bioenergy.gov/pdfs/AdvisoryCommitteeRDRecommendations.pdf .

ENDNOTES

1. Data from ORNL Analyses

2. Assumes 5.9×10^6 btu/barrel of oil, 13,161 btu/lb ethanol (high heating value), and oil consumption associated with gasoline is about 7.9 million barrel/day or about 2.9 billion barrels/year. Assumes delivered prices of biomass residues at $50/ton.

3. *Vision for Bioenergy & Biobased Products in the United States*, Biomass R&D Technical Advisory Committee, October 2002.

4. National Corn Growers Association, World of Corn, based on data from USDA National Agricultural Statistics Service, 2000 Crop Production Annual Summary.